P033580/EPM

PATENT SPECIFICATION

(11) 1 490 535

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(21) Application No. 48077/74 (22) Filed 6 Nov. 1974
(31) Convention Application No. 7 315 058
(32) Filed 6 Nov. 1973 in
(33) Sweden (SW)
(44) Complete Specification published 2 Nov. 1977
(51) INT CL² C21D 1/02; C22C 38/04
(52) Index at acceptance
B3V 3
C7A 747 748 749 772 777 77X 780 782 A249 A25Y A276 A279 A28X A28Y A30Y A316 A319 A320 A323 A326 A329 A339 A349 A35Y A366 A369 A37Y A385 A387 A389 A409 A439 A459 A48Y A505 A507 A509 A51Y A523 A525 A527 A539 A53Y A541 A543 A545 A547 A549 A54X A55Y A571 A574 A577 A579 A587 A589 A58Y A591 A593 A59X A609 A61Y A629 A671 A673 A675 A677 A679 A67X A681 A683 A685 A687 A689 A68X A693 A695 A696 A697 A698 A699 A69X A70X

(19)

(54) MANUFACTURING A HARDENED STEEL ARTICLE

(71) We, NORRBOTTENS JÄRNVERK A.B., a Swedish Body Corporate of S—951 00 Luleå, Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method of manufacturing a hardened steel article, particularly one with small wall thickness and good dimensional trueness.

For producing hardened and possibly tempered thin details, for example of thin sheet metal, preferably below 3 mm, with good dimensional trueness, heretofore the detail after having been formed in a conventional manner was taken out of the forming apparatus, positioned in a holder to prevent subsequent distortion, and thereafter hardened and, possibly, tempered. This procedure is complicated and involves high requirements on the hardenability of the steel used.

The present invention provides a method of manufacturing a hardened steel article, in which a blank of hardenable steel is heated to hardening temperature and thereafter placed in a forming apparatus in which the blank is formed to the desired final shape by being subjected to substantial deformation and simultaneous rapid cooling, such that a martensitic and/or bainitic structure is obtained while the blank remains in the forming apparatus, which serves as a gauge for preventing distortion of the blank.

Preferably a blank of uniform thickness is used, and preferably the thickness of the formed article at any point differs from the thickness of the blank by no more than 25% of the thickness of the blank.

The steel utilized as starting material is preferably a boron-alloyed carbon steel or carbon manganese steel. In order to obtain the desired combination of hardness and toughness which may render the tempering step unnecessary, a steel may be used which contains, by weight, less than 0.4% carbon, silicon in an amount depending on the steel production method but in general being insignificant, 0.5 to 2.0% manganese, at maximum 0.05% phosphorus and at maximum 0.05 sulphur, 0.1 to 0.5% chromium and/or 0.05 to 0.5% molybdenum, up to 0.1% titanium, 0.0005 to 0.01% boron, up to a total of 0.1% aluminium and possibly insignificant low contents of copper and nickel, possibly in contents of up to 0.2% each.

Preferably the steel contains less than or equal to 0.25% (preferably 0.15 to 0.25%) carbon, silicon in an amount depending on the steel production method but in general being insignificant, 0.5 to 1.5% (preferably 0.7 to 1.5%) manganese, at maximum 0.03% phosphorus and at maximum 0.04% sulphur, 0.1 to 0.3% chromium and/or 0.05 to 0.5% molybdenum, 0.02 to 0.1% (preferably 0.02 to 0.05%) titanium, 0.0005 to 0.007% (preferably 0.0005 to 0.005%) boron, 0.03 to 0.1% (preferably 0.03 to 0.07%) aluminium, and possibly low insignificant contents of copper and nickel, possibly in contents of up to 0.2% each.

The steel is heated to hardening temperature, i.e. to a temperature above Ac_3 where the steel will be in austenitic state. The steel preferably is heated to a temperature between 775° C. and 1000° C.

The forming operation is preferably a pressing operation, but the method can also use other forming techniques, such as drop forging, extrusion and explosive forming.

In the preferred pressing operation the blank

Hot rolled or cold rolled and annealed state:

δ_S kp/mm²	δ_B kp/mm²	δ_5 %
36–42	50–60	23–55

(δ_S = yield stress, δ_B = ultimate tensile strength, δ_5 = elongation at fracture).

Hardened state: The following guide values are obtained, depending somewhat on dimension and hardening medium:

δ_S kp/mm²	δ_B kp/mm²	δ_5 %	Hardness HRC	Toughness KCU 0°C kp/cm²
120–150	150–170	8–12	45–50	5–10

(HRC = Rockwell 'C' hardness)
(KCU = impact energy, tested in accordance with ISO/R83).

With respect to their weldability, the boron-alloyed steels are to be judged after their base analysis, thus their carbon and manganese contents, because the structure attained in the heat-affected zone is not sensitive to hydrogen embrittlement. The boron steels listed in the Table, therefore, can easily be welded as normal high-strength structural steels.

When the boron steel is to be welded prior to the forming and hardening, the properties of the base material after hardening can be attained also in the welding joint by using special electrodes adapted to the boron steels.

WHAT WE CLAIM IS:—

1. A method of manufacturing a hardened steel article, in which a blank of hardenable steel is heated to hardening temperature and thereafter placed in a forming apparatus in which the blank is formed to the desired final shape by being subjected to substantial deformation and simultaneous rapid cooling, such that a martensitic and/or bainitic structure is obtained while the blank remains in the forming apparatus, which serves as a gauge for preventing distortion of the blank.

2. A method as claimed in claim 1, in which the blank is heated to a temperature above AC_3.

3. A method as claimed in claim 2, in which the said temperature is between 775° C. and 1000° C.

4. A method as claimed in any of claims 1 to 3, in which deformation and cooling are carried out so rapidly that a fine-grain martensitic and/or bainitic structure is obtained.

5. A method as claimed in any of the preceding claims, in which forming is carried out between two tools, which are pressed together rapidly.

6. A method as claimed in any of claims 1 to 4, in which forming is carried out against one tool by means of a pressure medium.

7. A method as claimed in any of the preceding claims, in which the rapid cooling continues after deformation has been completed, the blank remaining in the forming apparatus.

8. A method as claimed in any of the preceding claims, in which cooling is effected by cooling parts of the forming apparatus.

9. A method as claimed in any of the preceding claims, in which cooling is effected by contacting the blank directly with a coolant.

10. A method as claimed in any of the preceding claims, in which the blank is of uniform thickness.

11. A method as claimed in claim 10, in which the thickness of the formed article at any point differs from the thickness of the blank by at most 25% of the thickness of the blank.

12. A method as claimed in any of the preceding claims, in which the hardenable steel contains, by weight, less than 0.4% carbon, 0.5 to 2.0% manganese, at maximum 0.05% phosphorus and at maximum 0.05% sulphur, 0.1 to 0.5% chromium and/or 0.05 to 0.5% molybdenum, up to 0.1% titanium, 0.0005 to 0.1% boron, and up to 0.1% aluminium; the balance being iron and impurities including silicon.

13. A method as claimed in claim 12, in which the steel contains, by weight less than or equal to 0.25% (preferably 0.15 to 0.25%) carbon, 0.5 to 1.5% (preferably 0.7 to 1.5%) manganese, at maximum 0.03% phosphorus and at maximum 0.04% sulphur, 0.1 to 0.3% chromium and/or 0.05 to 0.5% molybdenum, 0.02 to 0.1% (preferably 0.02 to 0.05%) titanium, 0.0005 to 0.007% (preferably 0.0005 to 0.005%) boron, and 0.03 to 0.1% (preferably 0.03 to 0.07%) aluminium.

14. A method of manufacturing a hardened steel article substantially as described herein with reference to the Example.

15. A hardened steel article manufactured by a method according to any of the preceding claims.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1977.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.